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ABSTRACT

Instructional feedback given to the learners during computer simulation sessions may be greatly improved by integrating educational computer simulation programs with hypermedia-based computer-assisted learning (CAL) materials. A prototype of a learning environment of this type called BRINE PURIFICATION was developed for use in corporate training in the chemical and food industry. The simulation part of BRINE PURIFICATION was constructed by means of the design system MacTHESIS, while the CAL part was constructed using HyperCard. BRINE PURIFICATION is designed for the training of process operators. In this paper, the process of specifying, constructing, and testing of BRINE PURIFICATION is described. A report on a comparison of the instructional effectiveness of this integrated environment with a learning environment in which a simulation program is combined with paper instructional materials concludes the report. Two tables present the responses of the subjects on an evaluation form and the distribution of time during the computer session. Three figures provide sample computer screen displays in the simulation program BRINE SimUlaTion and the hypermedium module BRINE tUTor and a flow chart of communication between the two programs. (Contains 21 references.) (ALF)

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COMPUTER SUPPORT OF OPERATOR TRAINING: CONSTRUCTING AND TESTING A PROTOTYPE OF A CAL(COMPUTER AIDED LEARNING) SUPPORTED SIMULATION ENVIRONMENT

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Instructional feedback given to the learners during computer simulation sessions may be greatly improved by integrating educational computer simulation programs with hypermedia-based CAL materials. We constructed a prototype of a learning environment of this type and called it BRINE PURIFICATION. The simulation part of BRINE PURIFICATION was constructed by means of the design system MacTHESIS, while the CAL material part was constructed by means of HyperCard. BRINE PURIFICATION is designed for the training of process operators. In this paper the process of specifying, constructing and testing of BRINE PURIFICATION is described. The surplus value is discussed of this integrated environment compared with a learning environment in which a simulation program is combined with paper instructional materials.

INTRODUCTION

In recent years, the frequency of use of simulation programs for corporate training in the chemical and food industry has increased dramatically. This increase has been enabled by a fast improving availability of the required hardware- en software facilities. Charney and Reder (1986) put forward, that the learning of new skills consists of three components:

- Learning the concepts and functionality of the skills
- Learning how the skills should be performed.
- Learning to perform the skills in practice (including the recognition of the conditions determining when a certain skill should be performed).

The components are mastered independently. The first two components may be learned in a purely theoretical way. However, practical work is required to master the third component. Usually this component can be mastered by means of on-the-job-training. However, commonly this component is mastered more efficiently when this on-the-job-training is combined with a function training in which educational computer simulation programs are applied (Alessi, 1988). The costs of the training may be greatly reduced, when this approach is followed. Furthermore, Alessi stated that tasks can be learned faster when an on-the-job-training is preceded by a series of simulation programs with a gradually increasing fidelity.

The major purpose of an educational computer simulation program is to provide learners with a presentation of a system on a computer screen. A system (in the context of educational simulation) is a limited part of the reality, selected because of its educational value. In this paper the simulation program BRINE SimUlaTion is described. The system, presented by BRINE SimUlaTion, is a brine purification plant. BRINE SimUlaTion is designed for training the process operators that control the brine purification process.

Usually high fidelity procedural simulations are used in operator training. These simulations are used for the automation of the tasks of the operator by means of repetitive execution of the

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tasks in a simulated working environment. However, the brine purification process is innovated frequently. Automating of operator tasks should be repeated after each innovation. It may be easier for the operators to cope with these changes when their mental model of the brine purification process is enhanced. Consequently the enhancement of the operators' mental model was considered more important than the automatization of the operators' tasks. BRINE SimUlaTion was designed for this purpose.

Physical simulations, combined with the discovery learning method, are most suited for mental model enhancing (Kolb & Goldman, 1973; Alessi & Trollip, 1985; Gorny, 1988; Breuer & Kummer, 1990). De Niet (1988) developed a physical simulation model of the brine purification process for scientific research. The educational application BRINE SimUlaTion was based on his model. BRINE SimUlaTion enables the operators to test and refine their mental model of the brine purification process by means of active experimentation.

A requirement for the method of discovery learning is that the program is used in an open, learner-controlled, context. This open context limits the possibilities severely for implementing automatic instructional feedback in the simulation program. However, the learner may use paper materials in combination with the program such as text books, exercises, instructions, and manuals. The learners' activities may be controlled by these paper materials. This type of learning environment, has been called **paper supported simulation environment** (Van Schaick Zillesen, 1990). Min (1987) stated that an educational computer simulation program cannot be effective if supporting paper materials are absent.

Hartley and Lovel (1984) suggest that adequate instructional feedback can be added to an educational computer simulation program by integrating it with CAL-materials made with an authoring system. This type of learning environment, has been called **CAL supported simulation environment** (Van Schaick Zillesen, 1990). Until recently no authoring system allowed the development of CAL materials with a user-interface similar to that of advanced educational computer simulation programs. Consequently a CAL supported learning environment could not be realized in a convenient way. However, recently a new generation of authoring systems (e.g., Course of Action) and Hypermedia systems (e.g., Hypercard) has been introduced. These systems support advanced features such as menu bars, pull down menus, dialogue boxes, interactive graphics, buttons, click-in regions, direct manipulation of objects on the screen and the use of external commands. An adequate simulation environment may be attained by integrating CAL materials generated by means of these authoring and Hypermedia systems with advanced educational computer simulation programs.

Advanced educational computer simulation programs and hypermedia share many characteristics. Both CAL-types are meant to be used in a purely learner-controlled context. The philosophy behind the user interface of both CAL-types (direct manipulation of visualized objects on the screen) is similar. The consistency of the user interface and that of the context is almost implicit throughout all parts of the software when the coaching materials for a CAL supported simulation environment are constructed by means of a Hypermedia system. Furthermore, prototypes of coaching materials can be developed in an extreme fast and highly interactive way using Hypercard, the most usual implementation of a hypermedia system. Consequently an adequate CAL supported simulation environment based on CAL materials made with Hypercard may be easier to realize than one based on CAL materials made with an authoring system.

We constructed a prototype of a CAL supported simulation environment by integrating the simulation program BRINE SimUlaTion with CAL materials made with Hypercard (BRINE tUTor). We called the complete prototype BRINE PURIFICATION. In BRINE PURIFICATION the simulation module BRINE SimUlaTion and the Hypermedium module BRINE tUTor communicate in both directions. BRINE tUTor sends information to BRINE SimUlaTion that defines the state (the simulation case, display arrangement and displayed variables) of BRINE SimUlaTion after it has been started. BRINE SimUlaTion sends information to BRINE tUTor that (after an analysis by BRINE tUTor) defines the feedback that is given by BRINE tUTor. In this paper we present our experiences about the design, construction and testing of BRINE PURIFICATION. Three topics are dealt with:

- The method, applied for design of BRINE PURIFICATION.
- A description of BRINE PURIFICATION.
- The testing of BRINE PURIFICATION.

In the last section of this paper, the surplus value of this CAL supported simulation environment compared with a paper supported simulation environment will be discussed. This discussion will be based on the experience gained by developing and field-testing BRINE-PURIFICATION.

DESIGN METHOD

In recent years we developed a universal design method for educational computer simulation programs (Min, 1987; Van Schaick Zillesen & Min, 1990). The method is designed on a hardware and software-independent level. Furthermore, we constructed several universal design systems (e.g., the RLCS-system, AppleTHESIS, THESIS, VAX-THESIS, HyperTHESIS and MacTHESIS). The design systems support the application of our design method on various computers (e.g., MINC, Apple //, IBM-PC compatible computers, Atari ST, Apple Macintosh). We extended the design system MacTHESIS (Min et al., 1986; Van Schaick Zillesen and Min, 1987; Van Schaick Zillesen, 1990) to enable the construction of CAL supported learning environments. We used the extended version of MacTHESIS (specified by Van Schaick Zillesen & Min, 1990) for the construction of BRINE PURIFICATION.

All educational computer simulation programs designed following our method consist of three major layers or shells. The outer shell is formed by the educational presentation of the simulated system. This state of the simulated system is presented to the learner by means of this shell. Furthermore, during the simulation session the learners interact with this part of the program. Several authors (e.g., Gorny, 1988; Daldrup & Gorny, 1989; Wedekind, 1985; Latzina & Wedekind, 1986; Alessi, 1988; Van Schaick Zillesen and Min, 1988a, 1988b) give criteria for this shell. Van Schaick Zillesen (1990, 1991) summarizes these criteria. The "heart" of the program is formed by the model code. The model code (often called 'compiled model') is the technical presentation of the simulated system in the computer program. By means of this code the program is able to simulate the behaviour of the simulated system. Between the outer shell and the heart of the program there is an interactive interface. The structure of this interface is decisive for the way the results of the model code are translated to the learner (e.g., in dynamic graphical displays or in model-driven animations). Furthermore, the actions of the learner controlling the program (e.g., starting the program, inspecting the values of variables or directly manipulating the presentation of simulated objects) are translated to the model code in this interface. Data can be transferred between the simulation programs and other educational software by means of this interface.

The construction of an educational computer simulation program requires the cooperation of experts in many domains such as: mathematical modelling, educational software engineering, instruction, curriculum design and graphical design. Modelling, designing educational computer simulation courseware, implementing the courseware within a curriculum and learning by means of the courseware each makes different demands on the technical knowledge of the user. Consequently all our design systems provide for a separate working environment for each of these activities. The working environments are later called the modeller's environment, the designer's environment, the instructor's environment and the learner's environment. In each working environment only a part of the software can be altered using tools. The part of the software that can be altered and the tools that can be used for this purpose, differ greatly from one environment to another. The environments have been described in detail by Van Schaick Zillesen (1990).

The specification of an educational computer simulation program is complicated by several phenomena. The complications are caused by the great speed at which the technology of educational computer simulation engineering has been developing during recent years. The main complicating phenomena are:
- a rapidly improving hardware performance.
- the development of new theories in the field of user interface design.
- a lack of data originating from research on which criteria for the specification of

simulations can be based.
- a limited availability of experts in the field of the implementation of educational computer simulation programs.

The complications mentioned above may make it is hard, or even impossible, to specify an educational computer simulation program completely and correctly at the start of the construction phase. Consequently models for the construction of educational materials implying distinct phases of product development such as pilot-research, design, specification, implementation, evaluation and revision are not suited for the construction of educational simulations. The rapid-prototyping model, designed for the construction of innovative software products instead of educational materials, gives more satisfying results (Van Schaick Zillesen, 1991). Zwart constructed an elaborated version of the rapid-prototyping model for the construction of educational computer simulation programs as part of his studies in educational science (Univ. of Twente; Internal Publication, Division of Educational Instrumentation Technology). Moonen (1991) discussed this model. When this model is followed, a first prototype is created as soon as possible, based on preliminary specifications. The prototype is revised based on the results of a formal evaluation by the members of the developmental team. This cycle of revision and formal evaluation is repeated several times. We experienced that 6 - 12 formal evaluations and revisions are needed before this cyclic phase of program construction is completed. At the end of the last revision the prototype is tested with learners in a real educational situation (summative evaluation).

During the cyclic phase of program construction, the prototype can be adapted to sudden changes in respect to hardware and software specifications. Furthermore, incorrect specifications (caused by a lack of empirical data or due to a lack of experience) can be corrected with great ease during this phase.

We developed and field tested thirteen prototypes of educational computer simulation programs in order to evaluate our design method (Van Schaick Zillesen, 1990). The design method proved to be domain independent; instructional simulation software for teaching physics, biology, chemistry, medicine, economy and for training process-operators was developed with great ease. Furthermore, the design method proved to be learner-population independent. Educational computer simulation programs designed by us are in use at institutes for vocational training, secondary education, process operator training and higher education.

BRINE PURIFICATION

In the eastern part of the Netherlands, there is a layer of rock-salt at great depth under the soil that is exploited for commercial purposes. Two types of pipes are used to get the salt out of the soil. With the pipes of the first type water is pumped into the layer of rock-salt, thereby dissolving the salt. The solution of the salt in the water is called brine. The brine comes up to the surface through the pipes of the second type. At the surface salt is gathered by reducing the brine by means of an evaporation process. However, the brine contains a few contaminations that have to be removed before the start of the evaporation process. The process in which the contaminations are removed from the brine is called the brine purification process.

The brine purification process is a slow developing process. Consequently it takes a long time before the consequences of an intervention in the installation can be observed. E.g., it may take 24 hours before an alteration of the flow of a component introduced in the installation influences the quality of the produced brine. Often the team of operators making the intervention is replaced by another team before these results can be observed. In other cases new disturbances may have occurred, causing the operators to make new interventions. For these reason operators rarely observe the results of an intervention independently. Consequently the operators' mental model of the reactions that take place in the process can hardly be enhanced by means of on-the-job-training.

Our educational simulation proceeds with a speed of approximately 1000 times real time. The operators to get quick, direct, responses to their actions because of this high processing speed. Furthermore, disturbing factors can be studied independently. Consequently our simulation may be a powerful tool for enhancing

the operators' mental model of the processes in the brine purification installation.

Learners' environment

In the learner's environment the operator controls the simulation in an interactive way. However, the operator is not able to adapt the program itself. The computer is as transparent to the operator as possible. The operator does not have to possess any knowledge or experience about computers, programming or informatics to be able to work with the software.
BRINE PURIFICATION consists of two parts: a simulation program, called BRINE SimUlaTion, and instructions, called Brine tUTor. We used the design system MacTHESIS for the construction of BRINE SimUlaTion. BRINE tUTor was made with HyperCard.

In BRINE SimUlaTion (Fig 1) three windows are present. In the first window the state of the brine purification plant is visualized by means of a diagram. Some structures in the diagram are coloured, e.g., taps, tanks with chemicals on the input side of the installation and reactors. Operators may control the installation by clicking in these coloured structures.

In the second window, a dynamic graph is shown. In this graph time registrations of concentrations in the input are shown. By means of this window, the input of the installation (which is dynamic) can be followed. The user can select the concentrations that are shown from a menu that appears when the user clicks in one of six coloured squares, shown at the bottom of the window. The colour of the square corresponds to the colour of the display of the time registration of the selected concentration.

In the third window, a dynamic graph is shown. In this graph time registrations of concentrations of chemicals are shown at several points in the brine purification process. By means of this window, the proceeding of the brine purification process can be followed. The user can select the concentrations that are shown and the points at which they are measured from a menu. This menu can be attained as described for the second window.

BRINE tUTor (Fig. 2) consists of so-called hypercards. Several types of information (or combinations of these types) are present on the hypercards of BRINE tUTor such as: text, graphic presentations, multiple choice questions and animations.

Brine tUTor is organized according to the structure of a cardbox. Four categories of cards are present:
- cards with information about the control of the instructions made with HyperCard
- cards with information about the brine purification process
- cards with information about the control of the simulation program
- cards with exercises

Operators can switch from one card to another by means of buttons present on the cards. Furthermore, they can select other cards by means of network-cards, which can be called up with a button present underneath the cards.

BRINE tUTor may give feedback to the operator, based on his actions. Several types of feedback may be given, such as:
- presenting another card with information
- showing a message on the present card
- superimposing a window with a message on the present card
- showing an animation on the present card or on another card
- changing text on the present card or on another card
- running the simulation program BRINE SimUlaTion

In Figure 3 a diagram of the system of information interchange between BRINE SimUlaTion and BRINE tUTor is presented. The state of BRINE SimUlaTion, immediately after its start, is controlled by Brine tUTor. By means of this control system, the simulation case in BRINE SimUlaTion is selected, corresponding with the exercise introduced in Brine tUTor. Furthermore, model entities relevant to the purpose of the selected exercise are displayed in the dynamic graphs. Moreover, in consequence of this control system the screen layout of BRINE SimUlaTion is defined; in this way the most relevant information can be shown immediately after the start of the simulation. At the end of the simulation the actions of the user during the simulation are analyzed. In this analysis three aspects were checked by means of an evaluation procedure:
- the change of entities, which should be changed to do the exercise correctly.

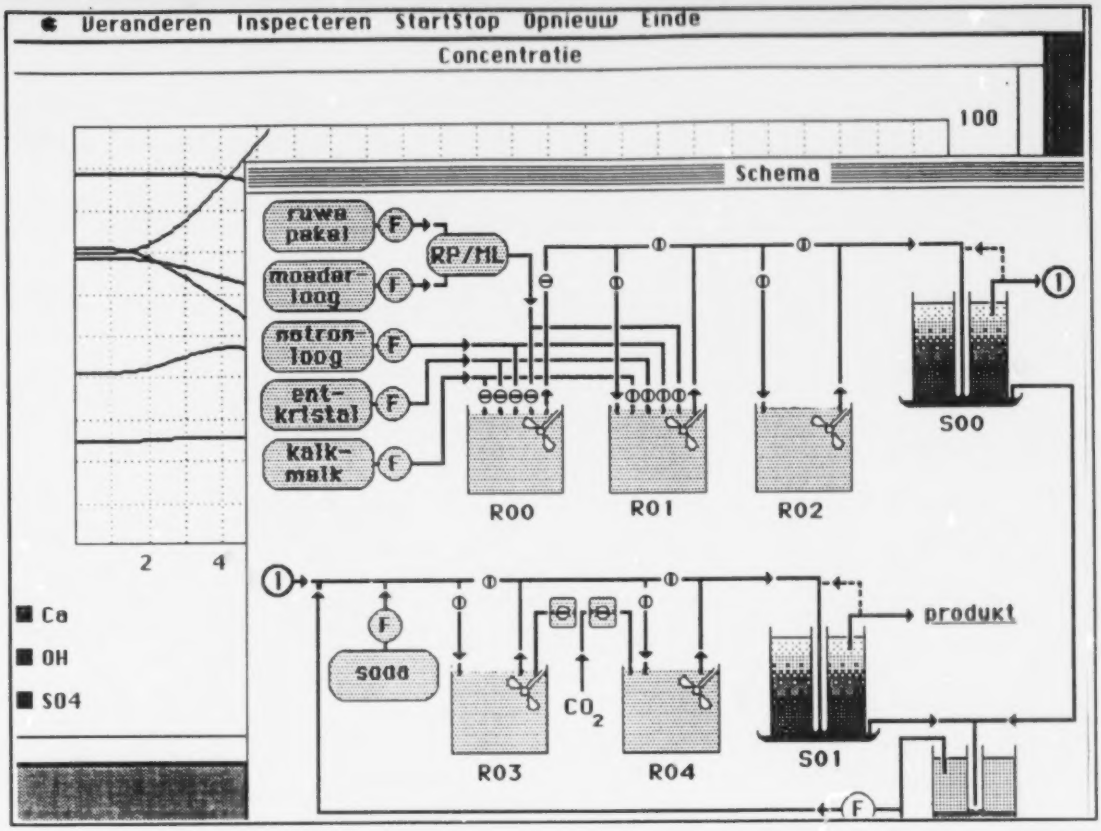

Figure 1. Screendump of BRINE SimUlaTion.

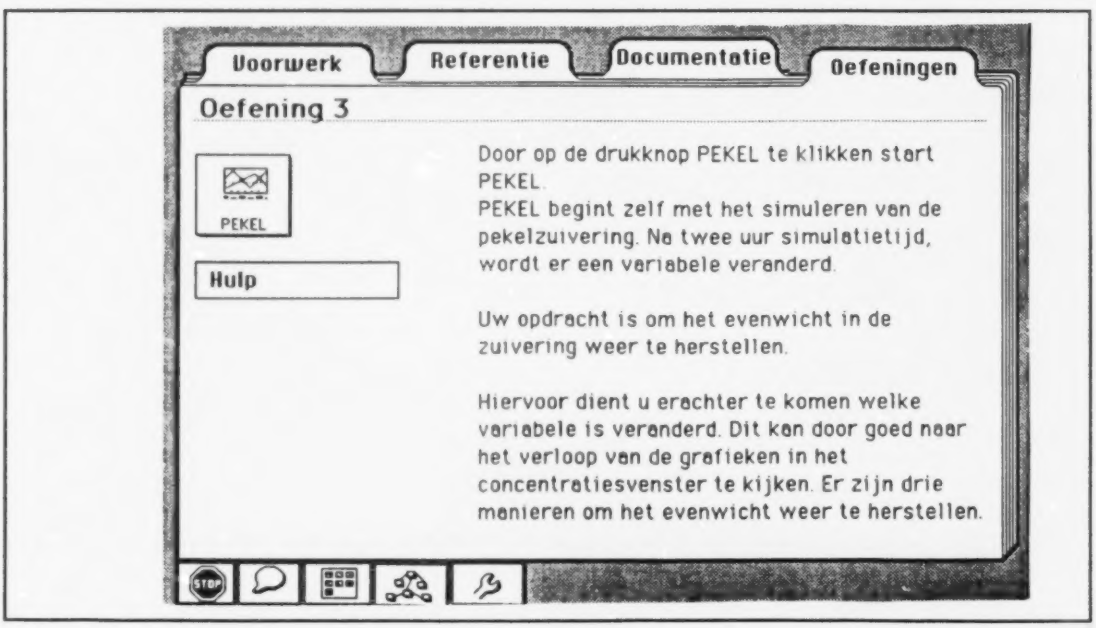
Voorwerk
Referentie
Documentatie
Oefeningen
Oefening 3
PEKEL
Hulp
Door op de drukknop PEKEL te klikken start PEKEL.
PEKEL begint zelf met het simuleren van de pekelzuivering. Na twee uur simulatietijd, wordt er een variabele veranderd.
Uw opdracht is om het evenwicht in de zuivering weer te herstellen.
Hiervoor dient u erachter te komen welke variabele is veranderd. Dit kan door goed naar het verloop van de grafieken in het concentratiesvenster te kijken. Er zijn drie manieren om het evenwicht weer te herstellen.
STOP

Figure 2. Screendump of BRINE tUTor.

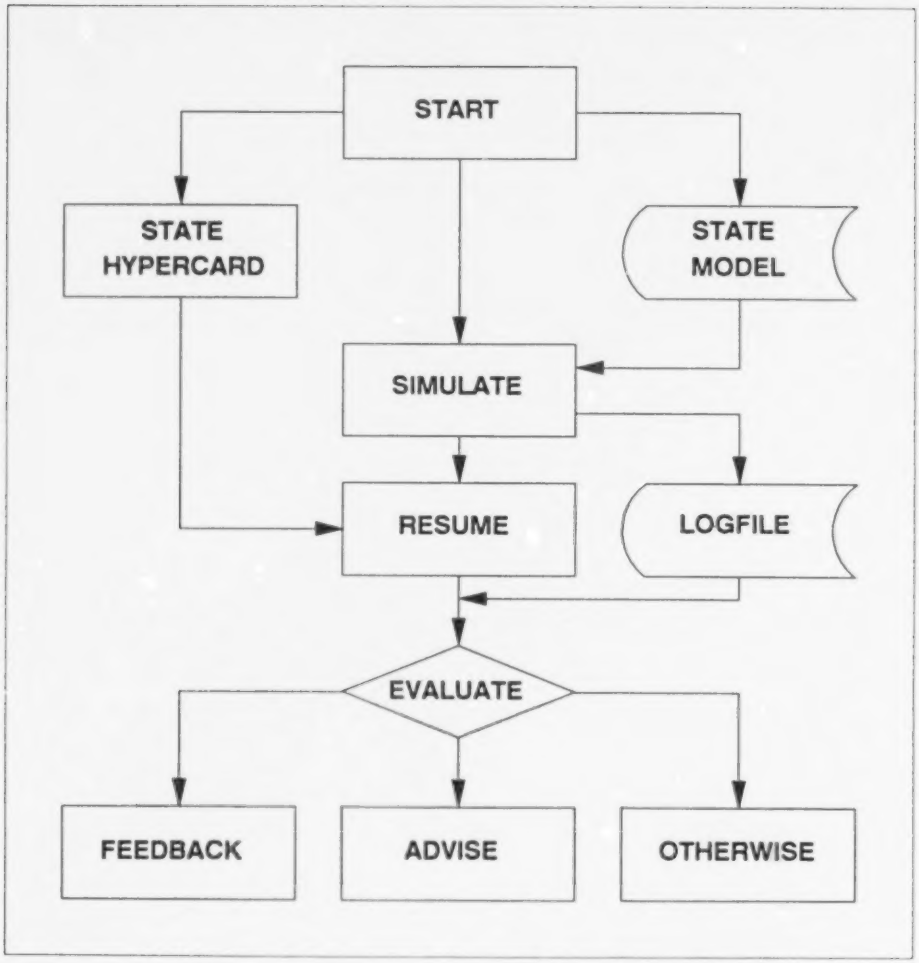

Figure 3. Communication between BRINE tUTor and BRINE SimUlaTion. A user, working with BRINE tUTor may start BRINE SimUlation by pushing a button, using the mouse. The message 'START' is send as soon as this button is pushed. At the same moment the state of BRINE tUTor is stored in the Hypercard stack. During the simulation session, the actions of the user are stored in a logfile. After the completion of simulation session, the messagehandler 'RESUME' will reset BRINE tUTor to the stored state. The message handler 'EVALUATE' will select the type of feedback corresponding to the completed simulation session, based on data stored in the logfile.

- the value of these entities (by means of range-checking)
- other entities, changed by the user

Based on the results of this evaluation, feedback is given to the user.

Instructors' environment

Several problems may occur when an instructor tries to implement an educational computer simulation program in a curriculum. The courseware may use an instructional strategy that does not conform to the instructor's educational philosophy. Furthermore, the language used by the courseware may differ from that used by the operators. Moreover, the terminology used in the courseware may not conform to that used in other educational materials (e.g., books) as used by the operators. In addition to these problems, the courseware may present the simulated system in a way that does not appeal to the operators (e.g., the presentation is too abstract or to concrete). The instructor may overcome these problems when he is able to adapt the resources (text, graphic information, cases and exercises) used by the courseware. This is why both BRINE SimUlaTion and BRINE tUTor use resources have that can be adapted easily.

BRINE tUTor, as all materials made with Hypercard, is organized in five user levels. In the learner's environment the user level of BRINE tUTor is automatically set on the browsing level. At this level the options available to the user include viewing cards, locating specific information in cards and using the buttons. However, the instructor can change all the properties of the instructions (or even create completely new instructions) in an interactive way by selecting a convenient user level. Furthermore, we designed tools (by means of HyperCard) that simplify the design of new exercises and to design new network-cards. An instructor is able to select a simulation case and a set of variables of the brine purification process by means of one of these tools. The simulation program displays the case and variables selected by the instructor when a button is pressed on the card of the new exercise. Furthermore, a tool enables the instructor to define rules for the feedback given to the operator at the end of the simulation. The instructor can adapt all the text and all the diagrams produced by BRINE SimUlaTion by means of an interactive resource editor.

EVALUATION

Experts with respect to the brine purification process were consulted frequently during the process of product development. Furthermore, a preliminary version of the prototype was tested by five teams (8 - 12 persons) of operators. The prototype was revised based on the comments of the experts and that of the operators. The test procedure was repeated using the revised prototype. After the second test the prototype was revised again. Furthermore, we developped paper materials with exercises to guide the user during the use of the prototype. The thus improved prototype was tested again. During this test two operators worked with the prototype BRINE SimUlaTion, combined the paper materials. During the computer session the operators were observed. When the operators had completed the last exercise, their opinion about the following subjects was asked for:

- The control of the program
- The paper material
- The screen design
- The structure of the software
- The difficulty of the materials

After the completion of the interview, the software was examined systematically for possible improvements. All comments made by the operators were recorded by means of an audio-recorder. The test was repeated five times. The results were used for improving the prototype. The thus improved prototype made part of BRINE PURIFICATION (besides BRINE tUTor).

METHOD

Experts

For the final test of BRINE PURIFICATION a group of nine experts from AKZO-Zout Chemie Hengelo (O) was available. All experts possessed advance knowledge about the structure of the simulated system (the Brine Purification installation) and about the relations within this system. The experts had no extensive experience in controlling the hardware used for the field-test.

Materials

Forms were filled in by the experts. The forms consisted of closed questions. Experts were

asked to indicate their preferences on a scale with five categories. The evaluation form consisted of four parts:

- Pre-knowledge. In this part of the form experts were asked about their knowledge of the brine purification installation, the Macintosh computer and the software used during the test.
- General Impression. In this part of the form experts were asked about their opinion of the product (BRINE SimUlaTion + BRINE tUTor) as a whole.
- The use. In this part of the form experts were asked about their opinion about subjects of BRINE tUTor such as buttons and search-help facilities. Furthermore the experts were asked if they had experienced problems regarding their orientation in the information space.
- Simulation. In this part of the form experts were asked about their opinion about the integration of BRINE SimUlaTion and BRINE tUTor.

During the computer session the experts were observed. Furthermore, their interactions with BRINE tUTor were logged automatically.

An introductory text was used to inform the experts about the goals and the contents matter of the prototype. The experts were informed that the prototype was meant to be used in an open context. The experts were advised to start by becoming familiar with the control of the program and trying to solve a simulation case afterwards. Furthermore, they were advised to use the instructional materials for looking up any information they needed.

Procedure

Only one computer system was available for the test. The experts worked individually. Each expert was allowed thirty minutes. At the start of the session, the expert was asked to read the introductory text. After this, the questions of the part 'Pre-knowledge' of the test form were answered. The computer session started wh en the answers to these questions had been completed. During the computer session the experts were observed. In case of an explicit request by the expert, the experimenter assisted him, to save time. In all other cases the experimenter did not interfere with the expert during the computer session. When the computer session was terminated, the rest of the answers to the questions of the evaluation was filled in.

RESULTS

The answers of the experts to the questions on the evaluation form are presented in table 1. This table shows that the following qualifications are appropriate to the prototype: 'clear', 'instructive', 'pleasant' and 'interesting'. Furthermore (according to the experts), the prototype can be used as a stand-alone learning tool and the coaching during the computer session is adequate.

During the computer sessions no problems were observed in respect of the control of the prototype BRINE tUTor. However, a few problems were reported in respect of the control of BRINE SimUlaTion. The more diverse control structure of BRINE SimUlaTion (consisting of buttons, a menubar, pull down menus and windows) compared with that of Brine tUTor (completely consisting of buttons), may have caused this effect.
The search tools are useful according to the experts. However, most experts indicated that they did not use the search tools (network tool and graphical path tool). Analysis of the logfiles showed that these cards have hardly been used (one expert used the network tool three times; all other experts did not use the search tools more than once). The opinions of the experts about the user about the prototype are presented in Table 1. The table shows that the presentation of the buttons was clear to the experts. Furthermore, they thought that the metaphors make the prototypes easier to understand. Moreover, they indicated that there was not a presentation of too much text and too few figures.

The organization of the prototype was clear to most experts. Furthermore, only a few of them reported that they had the feeling that they got lost in the prototype.

In Table 2 the relative time spent in functional parts of the prototype is presented. The experts spent most of their time studying the simulation part (the prototype BRINE SimUlaTion). During the study of Brine tUTOr the experts spended most of their time studying functional parts directly related to the exercises such as

instructions about the exercises and information about the control of the program. In contrast, the other two parts (information about the brine purification process and information about the control of Brine tUTor) of Brine tUTor were studied only for a few minutes.

The experts liked to work in an environment in which paper materials were not needed (Table 1). However, when the experts' preference in respect of the guiding materials was asked, the statement that paper materials were preferable was not rejected. Nevertheless, the experts suppose that the prototype can be used stand-alone. Furthermore, according to the experts the transfer of information from BRINE tUTor to BRINE SimUlaTion and vice versa was useful.

DISCUSSION AND CONCLUSIONS

In this paper our experiences regarding the design, construction and testing of a prototype of a CAL supported simulation environments (BRINE PURIFICATION) are presented. The simulation program (BRINE SimUlaTion) and the CAL-materials (BRINE tUTor) used in this environment both could be realized in a simple way. Furthermore, we succeeded in integrating the computer simulation program (constructed by means of MacTHESIS) with the CAL-materials (constructed by means Hypercard). This integration could be realized in a simple way as well.

Operators and experts both were able to control both parts of the prototype (BRINE SimUlaTion and BRINE tUTor) without great problems. However, the user interface of the prototype BRINE SimUlaTion was not quite transparent to the experts. Similar problems were not observed when the same prototype was tested with operators in a paper supported learning environment. The user interface of BRINE SimUlaTion is not completely consistent with that of BRINE tUTor. A user, who is just getting used to the user interface of one component of BRINE PURIFICATION, might be shocked when he is suddenly confronted with the user interface of the second component due to this inconsistency. This shock may occur in the CAL supported version of BRINE PURIFICATION, but not in the paper supported version. Thus, the difference in opinion of operators (working with the paper supported version) and experts (working with the CAL supported version) about the user interface of BRINE SimUlaTion may have been caused by this effect. The importance of a consistent user interface throughout the prototype is stressed by the difficulties observed.

A disadvantage of the used CAL supported simulation environment, compared with a paper supported one, lies in the sequential way in which the information about the subject matter is presented. This problem can be overcome by using separate windows, in which information about the subject matter of the program is presented parallel to the simulation programs. Prototypes of CAL supported simulation environments in which the simulation program can be presented parallel to the reference material, may give improved results compared with the present prototypes. In particular operators learning concepts new to them may benefit from this improvement. A new prototype of BRINE PURIFICATION supports this method of parallel instruction presentation. For this purpose the prototype makes use of the advanced features of the Apple Macintosh Multi-finder system. The prototype will be demonstrated during the conference.

A system of providing (delayed) feedback to the user was realized in BRINE PURIFICATION. This feedback was appreciated by the experts working with the prototype.

Experts working with BRINE PURIFICATION were free to select their own route. No fixed pattern of exploration could be established. Each expert followed his own route. However, it did not seem that the experts were just wandering about, since even reference material that was hard to find was studied intensively. The observed difference between the learning route followed during both tests shows that the degree of individualization of the learning process can be controlled by means of the guiding materials. In the prototypes designed by us, these guiding materials can be adapted in a simple and effective way.

The promising results of the test suggest that paper materials, inevitable until now for guiding the operator working with a simulation program during the learning process, can be replaced by hypermedia. In this way an almost perfect integration can be achieved. The user interface

and the level of coaching by the software remain the same in the total package (simulation program + guiding materials).

CAL supported simulation environments can be used stand-alone. Instructors and paper materials are, in principle, not necessary during the simulation sessions. The prototypes can be designed in a very effective way by means of the extensive use of interactive software (e.g., Hypercard, MacTHESIS, MacPaint, PixelPaint). It is very easy to adapt materials made by means of Hypercard. Instructors may use this option to adapt the learning environment to the needs of their operators. Furthermore, the instructor can design new exercises in an interactive way by means of tool programs. The importance of tools of this kind available to hypermedia systems for educational purposes has been stressed by Calabro (1990).

Most hypermedia systems (e.g., Hypercard) offer excellent opportunities to use other advanced educational materials such as interactive video and eperts systems. Furthermore, most Hypermedia systems are able to exchange data with these materials. Consequently, a future integration of simulation environments with other advanced educational materials will be easy to realize in simulation environments that are supported by hypermedia based CAL materials. This approach offers many advantages. Realistic images can be created by means of video-techniques. Interactive, student-controlled, model-driven desktop video programs may be realized following this approach. Furthermore, expert systems may be used for evaluating the pattern of operator-program interactions. The results of these evaluations may be used for adapting the instructional feedback given to the operator. The coaching of the operator during the learning process (the most important problem with regard to educational software used in an open context) may be greatly improved following this approach. A focal point of our future research will be the development of a universal design method for the design and construction of educational software that makes use of these advanced features. The method will be based on empirical data gathered by means of constructing and field-testing prototypes. New versions of our universal design systems THESIS and MacTHESIS are under development, supporting the construction of the prototypes required for this research.

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Table 2. Results of the field-test of BRINE-Purification. Distribution of time during the computer session (in percentages of the total duration of the computer session)

Functional Part	*Time (%)*
Simulation programs (exercises)	65.3
Instructions about exercises	10.9
Information about the control of BRINE PURIFICATION	14.9
Information about the brine purification process	4.6
Information about the control of Brine tUTor	4.3

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Table 1. Results of the field-test of the prototype BRINE-PURIFICATION; answers to questions on the evaluation form (from Van Schaick Zillesen, 1990)

Qualification	*Non-response*	*Mean*	*s.d.*
The prototype is clear (clear = 1.0; not clear = -1.0)	0	0.28	0.38
The prototype is instructive (instructive is 1.0; confusing = -1.0)	0	0.56	0.50
It is pleasant to work with the prototype (pleasant = 1.0; not pleasant = -1.0)	0	0.67	0.42
Working with the prototype is interesting (interesting = 1.0; not interesting = -1.0)	0	0.67	0.42
The prototype can be used on a stand-alone basis (agree = 1.0; disagree = -1.0)	1	0.56	0.71
The auto-start of cases (immediately showing the required display) is useful (agree = 1.0; disagree = -1.0)	0	0.61	0.69
It is pleasant that paper materials are not needed (agree = 1.0; disagree = -1.0)	0	0.67	0.61
The search tools are useful (agree = 1.0; disagree = -1.0)	1	0.81	0.40
Too much text and too few illustrations are presented (agree = 1.0; disagree = -1.0)	0	-0.50	0.59
I would prefer paper manuals with information about the purification process and the control of the simulation program (agree = 1.0; disagree = -1.0)	0	-0.28	0.91
The guidance of the user by the prototype is sufficient (agree = 1.0; disagree = -1.0)	0	0.39	0.75
The organisation of the prototype (in four functional parts) is clear (clear = 1.0; not clear = -1.0)	0	0.28	0.63
During the use of the prototype I felt lost (lost = 1.0; not lost = -1.0)	0	-0.28	0.72
The indication of the buttons was clear (clear = 1.0; not clear = -1.0)	1	0.75	0.39
The functioning of the buttons was predictable (predictable = 1.0; unpredictable = -1.0)	0	0.67	0.42
The network tools were useful (useful = 1.0; not useful = -1.0)	2	0.29	0.50
Did you use the information presented by means of the network tools? (frequently = 1.0; not used = -1.0)	1	-0.25	0.71
The prototype uses metaphors, like that of a map or a cardbox. The metaphors make the information easier to understand (agree = 1.0; disagree = -1.0)	2	0.43	0.56
Was it clear that the cases of BRINE PURIFICATION start automatically? (clear = 1.0; not clear = -1.0)	0	0.78	0.46
Brine tUTor gave feedback on your actions during the use of BRINE PURIFICATION. Did you like this feedback? (pleasant = 1.0; not pleasant = -1.0)	1	0.69	0.45

N persons = 9. A scale with five categories was used for all questions.